



Research Paper

The first detailed report for invasive *Erigeron annuus* (L.) Pers. (daisy fleabane) in Republic of Macedonia

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ABSTRACT

Detail survey of population of *Erigeron annuus* (L.) Pers., an invasive plant species native to eastern North America, were made in three border locations in north-western, northern and eastern parts of the Republic of Macedonia. The surveys revealed an intensive growth and different dense population of *E. annuus*. The population density was not quantified, but several stands of different sizes were found. A rapid ecological risk assessment, mainly based on knowledge about invasion histories in South-Eastern and Central European countries, showed that this specie is a serious threat to Macedonian biodiversity, particularly, in the North-western part, where dense stands of *E. annuus* monoculture were recorded. Biological invasions of *E. annuus* affects biodiversity worldwide through its fast-growing ability and high seed production, phenotypical plasticity in the native range with regard to the availability of soil nutrients and compounds released to the soil over the period of plant growth. Consequently, the invaded ecosystems suffer from significant losses in economic and cultural values.

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INTRODUCTION

Subtribe *Conyzinae* includes *Erigeron*, New World *Conyza*, the North American genus *Aphanostephus*, and a small group of South American species segregated as the genera *Apopyros*, *Darwiniothamnus*, *Hysterionica*, *Leptostelma*, and *Neja* (Nesom, 2008). The *Conyzinae* comprises about five hundred (500) species, and the genus *Erigeron* encompasses over four hundred (400) species found nearly worldwide (Noyes, 2000), of which two- *Erigeron annuus*, and *Erigeron acer* have been recorded in the Macedonian flora (Lozanovski, 1994).

E. annuus (L.) Pers. (syn. *Stenactis annua* (L.) Ness) (Asteraceae) known also as the daisy fleabane or annual fleabane, is a winter-annual species (or occasionally biennial) native to eastern North America (Stratton, 1992). It is a specie of tall grass prairies (Wilson and Hartnett, 1998; Edwards et al., 2006), which has probably spread as a weed and considerably expanded its range also in North America (Cronquist, 1995). *E. annuus* has spread successfully into many parts of the world, including

Europe, Asia, Australia. It was originally introduced into Europe in 17th century as an ornamental plant (Rothmaler et al., 1994) primarily grown in old estates, farmsteads and especially in old rural cemeteries.

Presently, *E. annuus* is one of the one hundred and fifty (150) most widespread alien plant species in Europe (Weber and Gut, 2004; Lambdon et al., 2008; Jogan et al., 2012), especially abundant in woodlands (Krtivojević et al., 2012), disturbed and ruderal habitats, such as roadsides, railway lines and waste areas (Edwards et al., 2006; Trtikova et al., 2011). It is listed as one of the fifty (50) most frequently found invasive species in Germany (Kowarik, 2002). In the countries of Central and South-East Europe, *E. annuus* is a problematic weed in moist and semi-open habitats. Together with adventive invasive plant *Ailanthus altissima*, *E. annuus* is the most present in both, semi-natural and artificial habitats in Romania (Anastasiu and Negrean, 2005). In Switzerland, it occurs mainly in the lowlands up to an altitude of 1790 m (Becker et al., 2005).

According to Szatmari (2012) *E. annuus* mostly invades hayfields and grasslands, but can occur on sand dunes.

Adventive weed species belonging to the family Asteraceae, such as *A. artemisiifolia*, *C. canadensis*, *G. parviflora*, *X. strumarium* and *S. annua*, are very aggressive weeds in Serbia (Konstantinović et al., 2010). *C. canadensis* and *E. annuus* are two species among the most dangerous invasive weed species in Hungary (Botond, 2005). In Slovakian agrocenoses this weed was classified into 1a category according to its invasiveness and expansiveness (Gojdičová et al., 2002).

S. annua is often present in semi-open and open pedunculate oak habitats (Bobinac and Radulović, 2002; Pap et al., 2012). The proportion of *S. annua* coming from the surroundings disturbed by forest regeneration processes on large clear-cut areas significantly increases (Klimo et al., 2011). Study of the seed bank of herbaceous understorey in weedy abandoned vineyard, edge and adjacent forest interior of an oak forest community (*Quercetum petraeae-cerris*) widespread in Central-Europe showed that the highest specific seed density scores were detected for *S. annua* (Koncz et al., 2011; Koncz, 2013).

Further, invasiveness of *S. annua* was confirmed in the aquatic systems. For example, in Slovenian, aquatic environment was examined and 22 invasive alien plant taxa identified, of which the species *I. glandulifera* and *S. annua* were the most frequent (Kovač, 2014).

GENERAL DESCRIPTION

E. annuus (from Greek *eri*, "early," and *geron*, "old man," thus meaning "old man in the spring," referring to the fluffy, white seed heads and the early flowering and fruiting of many species, and Latin *annuus* for "yearly" usually referring to a plant which lives only one season) is a native annual or biennial plant that measures approximately 30 to 150 cm in height, branching occasionally in the upper half to form flowering stems. The central stem has spreading white hairs throughout its length. *E. annuus* has two different types of leaves; lanceolate-to-ovate, with long basal leaves measuring approximately 15 cm in length and covered in coarse hairs. The leaves along the stem are considerably smaller, toothed, clasping, and also hairy. Small clusters of daisy-like composite flowers occur toward the apex of the plant, each measuring about 1.5 to 2 cm across. The central disk florets are numerous, yellow in colour and very small; they are surrounded by 50 to 120 white ray florets. Both florets can be self-fertile. The flower buds often have conspicuous white hairs. The blooming period begins in early summer and continues intermittently until the fall, usually with a lull during the hot weather of late summer. A mild fragrance is sometimes detectable. The root system is fibrous and spreading. The achenes have tufts of small hairs (which they sometimes lose); and are distributed by the wind.

Phenology

E. annuus is triploid ($2n=27$) and predominantly apomictic, reproducing by tiny (25 µg) wind-dispersed seeds with each plant being able to produce 10,000 to 50,000 genetically identical seeds in a season (Stratton, 1989). Seeds normally germinate in late summer-early autumn (August to September), and plants overwinter as rosettes from which flowering stems develop in the following spring (April to May). The species bolts and flowers in early summer (June to July).

Distribution of *Erigeron annuus* (L.) Pers. in Republic of Macedonia

In this record, the author of the paper gave the first detailed report for current situation with invasive *E. annuus* (L.) Pers. in Republic of Macedonia (Figure 1). In the early to mid-summer in 2014, during the field work trials with herbicides in three different locations, an intensive growth of *E. annuus*, aggressive and invasive alien species to the Macedonian flora was revealed.

North-western Macedonia

On the 24th June 2014, a visit to maize field trials with herbicides near the village Gorno Sedlarce (41° 56' 12" N and 20° 56' 38" E; Altitude 472 m) located in the North-Western mountainous part of the Republic of Macedonia, recorded an abundance of *E. annuus* (Figure 2). The places where *E. annuus* was found are roadsides, ruderal areas and damp woodlands near the base of the Sharr Mountains, the biggest mountain in the Republic of Macedonia (Figure 3).

On the 24th of June 2014 and the 14th July, 2014, the site was surveyed to estimate the extent of the invasion. These surveys revealed an intensive growth (intensive flowering stage) and a medium to high dense population of *E. annuus*. The population density was not quantified, but several stands of different sizes were found. The largest stands were approximately 20 to 25 m at their widest point. During the second survey, the author extended the area of observation, and the plant was found mainly in human influenced and man-made habitats such as shrubbery, ditches, hedges and alongside canals. Out of these areas, several single plants could be observed as smaller forms, even in the arable land, that is, wheat crop fields (Figure 4).

Northern Macedonia

On the 19th of September 2014, a visit to maize field trials with herbicides near the village Marino (41° 59' 16" N and 21° 35' 25" E; Altitude 410 m) located on the eastern part of the Skopje valley, recorded low to medium dense



Figure 1. *Erigeron annuus* (L.) Pers. (daisy fleabane) a: steam elongation stage (6 to 8 leaves); b: inflorescence emergence; c: flowering (photographs by Z. Pacanoski).



Figure 2. Map of the Republic of Macedonia showing where the invasive *Erigeron annuus* (L.) Pers. (daisy fleabane) was found. The green area is the area in the top left of the country where the village Gorno Sedlarce is situated and where the plants were observed. The blue areas are lakes.



Figure 3. High dense population of *Erigeron annuus* growing in the man-made habitats (photographs by Z. Pacanoski).



Figure 4. Several plants of *Erigeron annuus* growing in the wheat crop fields (photographs by Z. Pacanoski).



Figure 5. Map of the Republic of Macedonia showing where the invasive *Erigeron annuus* (L.) Pers. (daisy fleabane) was found. The green area is the area in the middle-up of the country where the village Marino is situated and where the plants were observed.

population of *E. annuus* (Figure 5). The places where *E. annuus* was found are roadsides, ruderal areas and wastelands near highway E 75 (Figure 6).

On the 19th and 29th of September 2014, the site was surveyed to estimate the extent of the invasion. These surveys revealed an intensive growth (flowering to development of fruit stages) and a low to medium dense population of *E. annuus*. The population density was not quantified, but several stands of different sizes were found. During the second survey, the author extended the area of observation, and the plant was found only in human influenced and man-made habitats.

Eastern Macedonia

On 28th June, 2014, a visit to rice field trials with herbicides near the village Blatec (41° 50' 12.58" N and 22° 34' 42.42" E; Altitude 703 m) located on the eastern part of Kočani rice valley recorded low dense population of *E. annuus* (Figure 7). The places where *E. annuus* was found are roadsides, ruderal areas and damp woodlands near streams which spring from the Plačkovica Mountain (Figure 8).

On the 28th of June 2014 and the 24th of July 2014, the site was surveyed to estimate the extent of the invasion. These surveys revealed an intensive growth (intensive flowering



Figure 6. Population of invasive *E. annuus* growing in the man-made habitats near the village Marino, Republic of Macedonia (photographs by Z. Pacanoski).

stage) and low dense population of *E. annuus*. The population density was not quantified, but several stands of different sizes were found. The largest stands were few metres at their widest point. During the second survey, the author extended the area of observation, and several single plants were observed as smaller forms, even in the edges of neighbouring rice fields (Figure 9).

Research by Rutkowski (2004) revealed that the biotopes that are most suitable for *E. annuus* are those that have been affected by humans. The studies of species dynamics in Lithuania suggest that in the initial phases of invasion, that started a few decades ago (Tunaitienė et al., 2014), the species prefers human-affected sites, such as urban areas and old cemeteries (Patamsytė et al., 2013), while on later invasion stages it appears to be a successful frequent invader in dump woodlands and weedy sites (Kovačević et al., 2011, Vasić et al., 2012). In habitats where *E. annuus* was detected, it most commonly grows together with nitrophilous plant species such as, *Urtica dioica* L., *Artemisia vulgaris* L., *Rubus caesius* L., *Daucus carota* L. and *Conyza canadensis* (L.) (Figures 6 and 8). Similar findings are reported by Medvecká et al. (2009). According to them, *E. annuus* (*S. annua*) forms moderately species-rich two-layered communities accompanied by *Artemisia vulgaris*, *Melilotus albus*, *Pastinaca sativa*, *Tanacetum vulgare* and *Solidago canadensis*, dominated in the upper layer, and *Achillea millefolium*, *Daucus carota*, *Odontites vulgaris*, *Plantago major*, *Poa pratensis* and *Trifolium pratense* in the lower layer. The community prefers sunny and warm habitats with well aerated soil.

Due to its preference for moist areas, rainfall might seem to be a key predictor of *E. annuus* distribution in Republic of Macedonia. In that context, the places where it was found belong to regions with medium to high annual precipitation (564 to 795 mm) (Kostov, 2003). Thus, it is primarily the

indicator plant of humid conditions (Botond, 2005). However, *E. annuus* occurred in European locations with low annual precipitation (For example, Western Romania with 400 mm) (Szatmari, 2012) to heavier precipitation (For example, North-western Croatia with 1262 mm annual precipitation) (Vuković et al., 2010).

Taking into consideration that, *E. annuus* was found in human influenced and man-made habitats in border regions, the introduced pathway may have probably been human activity. The places where it was found are much closed to the Albania, Serbia and Bulgaria countries where *E. annuus* is considered as one of the most widespread alien plant species (Barina et al., 2013; Vrbničanin, 2013; Vladimirov, 2013). It is well-known that big seed quantities of *E. annuus* (each plant being able to produce 10,000 to 50,000 seeds in a season) are sufficient for establishing a new plant population in favourable environmental conditions. High rates of seed production and explosive dispersal from capsules spread solely by wind, enables *E. annuus* to spread rapidly (Stratton, 1988), even in the arable land (cereal fields, perennial fodder fields, forest plantations) and beyond its altitudinal limit (Kovačević et al., 2011; Nestorović, 2005; Majekova and Zaliberova, 2008, Trtikova, 2008).

Ecological impacts

The discovery of a well-established population of *E. annuus* as a highly invasive alien species in the Macedonian flora, is a significant concern, particularly in the North-western part, where dense stands of *E. annuus* monoculture were recorded (Figure 3). Biological invasions of *E. annuus* affects biodiversity worldwide, and the invaded ecosystems may consequently suffer from significant losses in



Figure 7. Map of the Republic of Macedonia showing where the invasive *Erigeron annuus* (L.) Pers. (daisy fleabane) was found. The green area is the area in the right of the country where the village Blatec is situated and where the plants were observed.



Figure 8. Invasive *E.annuus* near the village Blatec, Republic of Macedonia (photographs by Z. Pacanoski).

economic and cultural values (Anastasiu and Negrean, 2005; Kubešová et al., 2010). As a species with potentially high negative influence on biodiversity, *E. annuus* is a threat to biodiversity in wet habitats, natural and extensively managed habitats, forest and floodplain woods and swamps, as the plant which is able to successfully compete

directly with native species for space, light and nutrients (Zelnik, 2012; Vasić et al., 2012).

E. annuus and tree species *Robinia pseudacacia* are the most frequent invasive alien plant species in grasslands on the territory of Austria (Essl and Rabitsch, 2002) and the most frequent invasive alien plant species in riparian zones



Figure 9. Several plants of *E.annuus* growing in the in the edges of neighbouring rice fields (photograph by Z. Pacanoski).

around the standing waters in Slovenia (Zelnik, 2012). *E. annuus* increasingly penetrates in nature-like habitats and might probably become a nuisance. Invasive behaviour has been met with on a coal mine heap in the surroundings of Liège (Frankard and Hauteclair 2009).

Further, the result of ecological risk analysis to nine (9) representative invasive alien plants in China showed that the ecological risk of *E. annuus*, *Ageratum conyzoides*, *Alternanthera philoxeroides* and *Mikania midrantha* is the highest (grade1-2) (Xie et al., 2009). Adverse effects on the surrounding native plants as well as those which grew in succession (Zhang, 1993; Zhang and Yu, 2001) can be exhibited by compounds released to the soil over the period of plant growth (Abhilasha, 2008).

The concentrations of the C10 polyacetylenes in *E. annuus* diffused to the soil were discovered to be inhibitory to the surrounding plants (Kobayashi et al., 1980; Economou et al., 2002). (+)-Erigeronic acid, isolated from the aerial parts, such as flowers, stems and leaves of *E. annuus* exhibits germination inhibitory effects on lettuce seeds (Oh et al., 2002). Similar to the investigation of Yan (2008), allelochemicals of *E. annuus* remarkably restrained the weight, root and seedling of corn plants.

The success of *E. annuus* as a good colonizer is due to the fast-growing ability and high seed production, as well

(Grotkopp et al., 2002). One single inflorescence may produce more than 10, 000 wind-dispersed light seeds (24.6 to 28.6 µg) (Stratton, 1989) with high dispersal ability; bear a pappus that facilitates wind transport on long-distance (Andersen, 1993; Cain et al., 2000). Intra-individual variation in seed mass of *E. annuus* plants helps in the utilization of heterogeneous environments (Rees and Westoby, 1997). Also, phenotypically plasticity in the native range with regard to the availability of soil nutrients, make *E. annuus* very adaptative to environmental heterogeneity (Stratton, 1991, 1994; Stratton and Bennington, 1998). For example, *E. annuus* plants maintained relatively high fitness up to the altitudinal limit of the species distribution, probably due to phenotypic plasticity (Trtikova, 2008). Broad environmental tolerance due to high phenotypic plasticity is likely to be particularly important during the early stages of invasion, as it may increase the range of habitats into which an introduced species can become naturalized (Sexton et al., 2002).

Conclusions for the Republic of Macedonia

Personal observations of *E. annuus* in the three localities in Republic of Macedonia suggest that it is a highly invasive

species, which is one of the 150 most widespread alien plant species in Europe. *E. annuus* is able to outgrow its competitors due to the fast-growing ability, autonomous seed production, versatile mating system of self- and cross-pollination, generalized pollination system, high and rapid production of achenes, high percentage and rapid germination rate and high dispersal capability of achenes. Taking into consideration these facts, the authors expect that in the very close future, it will rapidly establish itself in many other Macedonian regions, following the pattern seen over the past three centuries in North-Western and Central European countries.

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